

ACCELERATION AND SUPPRESSION OF RATS' RESPONDING TO AVOID FOOT SHOCK AND TAIL SHOCK¹

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Signalled response-independent shocks were superimposed on rats' wheel-turn responding to avoid shock administered to their feet through a grid floor or to their tails through fixed electrodes. In Experiment I, a tone paired with response-independent foot shock increased responding in three of four rats; a tone paired with tail shock increased responding in only one of four rats and suppressed responding in two rats. In Experiment II, a tone presented randomly with respect to response-independent shock had no reliable effect on responding to avoid foot shock or tail shock. In Experiment III, tail shock and foot shock were compared in a within-subject design while the temporal pattern of responding during conditioned stimuli was recorded. Responding during the conditioned stimulus preceding foot shock was characterized by initial suppression of responding at tone onset, followed by increased responding just before response-independent shock. Responding was suppressed throughout the conditioned stimulus preceding tail shock. Foot shock elicited bursts of responding, but tail shock did not.

Key words: conditioned acceleration, conditioned suppression, foot shock, tail shock, Sidman avoidance, wheel turn, rats

A conditioned stimulus (CS) preceding response-independent shock (US) can increase (Kelleher, Riddle, and Cook, 1963; Sidman, Herrnstein, and Conrad, 1957; Waller and Waller, 1963) or suppress (Bryant, 1972; Roberts and Hurwitz, 1970) avoidance responding, depending on interactions between responding and avoidable shock during the CS (Hurwitz and Roberts, 1971; Roberts and Hurwitz, 1970), the duration of the CS and the CS-US interval (Shimoff, 1972), the intensity of avoidable shock and intensity of the US (Scobie, 1972), and the duration of the CS and the response-shock interval (Pomerleau, 1970). These

experiments demonstrated many of the well-known interactions between Pavlovian conditioning and instrumental learning.

In studies of Pavlovian conditioning with electric shock as US, the physical locus of shock has varied from one experiment to another. Some experimenters have delivered shock through electrodes fixed to their subjects; others have delivered shock through grid floors to their subjects' feet. Often, the behaviors controlled by CS's signalling shock at different loci are similar. For example, Pomerleau (1970) and Shimoff (1972) used tail shock and foot shock respectively, and both experimenters observed suppression of lever-press responding. But sometimes, electric shock at different loci have effected different behavioral outcomes. Rat's heart-rate changes (Teyler, 1971) and vocalizations (Davis and Hubbard, 1973), appear to come under the control of a Pavlovian CS more reliably when the shock US is administered through fixed electrodes. And conversely, Barbaree and Weisman (1975) found foot shock more effective than tail shock as the US in a three-stage transfer-of-aversive control experiment. As reported previously, when conditioning sessions were conducted separately from avoidance sessions (Weisman and Litner, 1969) a CS signalling foot shock increased the rate of rats' avoidance respond-

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ing. But surprisingly, a CS signalling tail shock had no reliable effect on the rate of rats' responding to avoid foot shock.

The present work extended our comparison of foot and tail shock (Barbaree and Weisman, 1975) to include Pavlovian conditioning during shock-avoidance sessions. The conditioned stimulus and US were paired (Experiments I and III) or presented randomly (Experiment II) while rats avoided either foot shock or tail shock. The present series of experiments analyzed both conditioning and extinction of the Pavlovian effects on the avoidance response.

EXPERIMENT I

Experiment I compared the effects of a CS signalling an electric shock (US) on the rate of ongoing free-operant avoidance responding in two shock conditions. Rats were administered both the US and avoidable shock through either a grid floor or tail electrodes.

METHOD

Subjects

Eight female albino rats (190 to 250 g), retired breeders of the Fischer 344 strain, were obtained from Charles River Breeding Laboratories. Each rat was housed individually and had free access to food and water, except during experimental sessions. Rat S15 was omitted after completing part of the procedure in the tail-shock condition because of severe self-inflicted injuries to the feet and legs.

Apparatus

Avoidance sessions were conducted in two identical operant chambers, 22 by 28 by 24 cm. Each chamber had aluminum front and back walls and Plexiglas side walls and ceiling. The axle of a wheel manipulandum was mounted horizontally 12 cm above the chamber floor outside the chamber's front wall. The wheel protruded 3.5 cm into the chamber through a 10- by 11-cm opening in the front wall. The wheel manipulandum consisted of two circular Plexiglas discs 10 cm in diameter fixed vertically, one on each end of a horizontal Plexiglas tube 10 cm long and 6 cm in diameter. Around the circumference of these discs, horizontal stainless-steel rods placed 2.5 cm apart ran from disc to disc parallel to the Plexiglas cylinder. Four permanent magnets set in the wheel at 90° intervals closed a reed

switch four times in a full turn of the wheel. Each switch closure operated a "response feedback" relay mounted on the back of the front wall of the chamber. Foot shock was administered via stainless-steel rods spaced at 1.25-cm intervals parallel to the wheel. Tail shock was administered to the rat in a Plexiglas stall (11 by 14 by 19 cm) placed flush against the front wall of the avoidance chambers. When a stall was in place, the wheel manipulandum protruded through an opening in the front wall of the stall. A floor in each stall kept the rat off the electrified grid floor of the avoidance chamber. The rat's tail extended through a hole in the back wall of the stall and was restrained. Two flat 1-cm² copper-plate electrodes were taped about 2.5 cm apart along the longitudinal axis of the base of the rat's tail. Once placed in the stall, the rat could not disturb the connecting wires or electrodes, yet could turn the wheel in a posture similar to a rat on the grid floor of the avoidance chamber. A 1000-Hz tone (Grundig, Model TG-4 tone generator) presented through a speaker mounted above the ceiling of the avoidance chamber increased the sound-pressure level in the chamber to 80 dB (ref 0.0002 dynes/cm²) from a sound-pressure level of 76 dB maintained by white noise and noise from the exhaust fan. The two avoidance chambers were housed in separate sound-attenuating enclosures. Scheduling and recording equipment was located in a separate room.

High-voltage constant-current shock generators (Lafayette Instruments, Model A615) were individually adjusted to deliver 0.75 mA to rats of the Fischer 344 strain via the grid floors, front and back walls of the avoidance chambers, and the tail electrodes of the Plexiglas stalls. The grid-shock circuit placed successive grids in series through N-2 neon bulbs (Reynierse, Scavio, and Ulness, 1970). Approximately eight neon bulbs remained in the circuit when a rat received foot shock on the grid floor. Accordingly, the tail-shock circuit placed the rat in series with eight neon bulbs to match the foot-shock circuit. Measured under the conditions of the present experiments, the feet and tails of the rats offered approximately 100 and 160 K ohm resistance, respectively, to ac. These values are only 4% and 7% of the 2 to 3 Megohm internal resistance of the shock source. Thus, it appears reasonable to assume that in the present experiments,

rats received very nearly the same intensity of electric shock to the tail as to the feet.

Procedure

Experiment I had four successive phases: (1) avoidance training followed by (2) 80-min avoidance sessions in which the tone was presented alone in pretest, followed by (3) shock in conditioning and (4) alone again in extinction.

Avoidance training. Each rat was trained to turn the wheel to avoid unsignalled shock (Sidman, 1953). Brief (0.3 sec) electric shock occurred every 5 sec in the absence of wheel turning, *i.e.*, the shock-shock interval was 5 sec. Each wheel turn postponed shock for 20 sec, *i.e.*, the response-shock interval was 20 sec. Rats could avoid all response-dependent shock by emitting responses with interresponse times shorter than 20 sec.

Rats were assigned at random to foot shock (S15, S16, S24, and S30) or tail shock (S9, S10, S23, and S29) as the negative reinforcer. Avoidance training continued for 8 hr (S9, S10, S15, and S16) or 26 hr (S23, S24, S29, and S30). After the first half of training, each rat was shifted to the other method of shock administration. Thus, before the pretest, the rats had an equal amount of training with each negative reinforcer. Then, within pairs of rats with identical training sequences, rats were randomly assigned to either foot shock (S10, S16, S24, and S29) or tail shock (S9, S15, S23, and S30) for the remainder of the experiment.

Pretest, conditioning, and extinction. During the next four pretest sessions, 20, 5-sec tones were presented on a variable-time (VT) 3-min schedule (range 1 to 5 min). During each of the next nine conditioning sessions, the tone was scheduled as in pretest sessions, but tone offset coincided with the onset of a 1-sec response-independent electric shock. During each of the next three extinction sessions, the tone alone was scheduled as in pretest.

The numbers of responses and shocks in each of seven 5-sec intervals, beginning 15 sec before tone onset and ending 15 sec after tone offset, were recorded. Two procedures reduced the influences of bursts of responding engendered by response-dependent shock on the calculation of avoidance rates of responding for these seven intervals: (a) the occurrence of response-dependent shock in any of the seven intervals resulted in omission of the data for

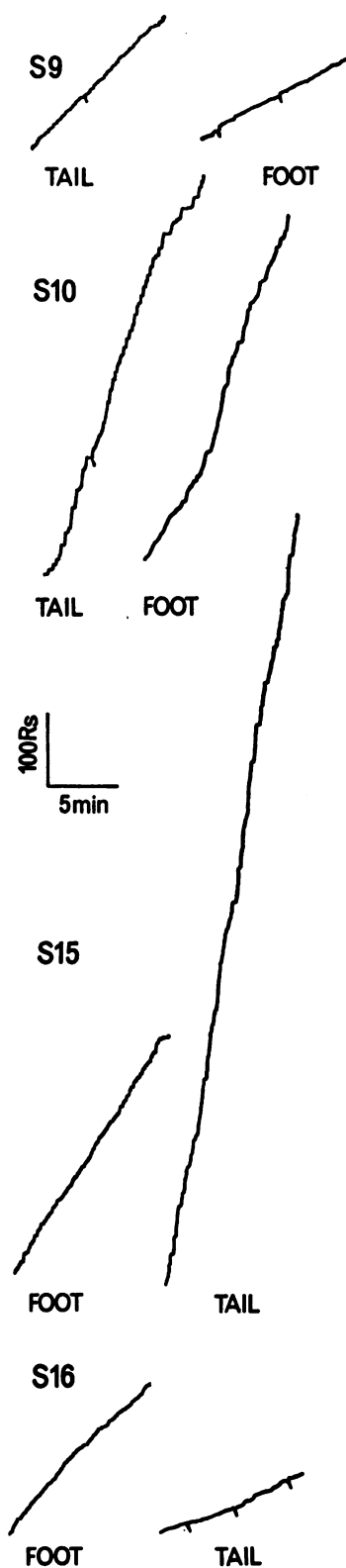
that trial, (b) although the avoidance schedule remained in effect throughout each 80-min session, neither tones nor response-independent shocks were presented during the initial 20 min of any session, because the first few minutes of a session were sometimes characterized by disproportionally high shock rates.

RESULTS

Figure 1 presents cumulative records from the last 10 min of foot-shock and tail-shock avoidance training before tone pretest for four rats. No obvious differences appeared after several hours of training between rats' responding to avoid foot or tail shock, either in the rate of wheel turning or in shock density.

Rates of responding during the 5 sec immediately preceding tone onset and during the tone are shown in Figure 2. In Figures 2 and 5, joined brackets shown for the initial session in each phase are the standard errors of the mean within that phase. Brackets did not show effectively and were therefore omitted when a standard error was less than two responses per minute. During pretest, tone presentation increased the rate of responding at least slightly and at least in some sessions in seven of eight rats. During conditioning sessions, consistent differences between responding during and before tone were obtained in seven of eight rats. However, the direction of the changes in the rates of responding in response to the tone were not consistent between rats or between conditions. In the foot-shock condition, the tone increased responding in three rats and suppressed responding in the remaining rat. In the tail-shock condition, the tone increased responding in only one rat, suppressed responding in two rats, but had no consistent effect in the remaining rat. During extinction sessions, the tone suppressed responding in each rat independently of the physical locus of shock.

Rates of responding in the 5 sec immediately following tone offset are shown in Figure 3. During conditioning sessions, the posttone interval began with response-independent shock. In the foot-shock condition, posttone responding increased gradually in bursts of high-rate responding from the first to the last conditioning session to rates well above those of either pretest or extinction sessions. However, in the tail-shock condition, rats responded only slightly more during the post-



tone interval during conditioning than during pretest sessions. Posttone responding tended to decline over extinction sessions.

Trials excluded from Figures 2 and 3 due to bursts of responding generated by the occurrence of avoidable foot shock had a relative frequency of 4% in pretest, 9% in conditioning, and 12% in extinction, while trials excluded due to the occurrence of avoidable tail shock had a relative frequency of 7% in pretest, 12% in conditioning, and 28% in extinction.

Figure 4 shows avoidable shocks per hour delivered under the S-S interval (*i.e.*, following another shock) and total shocks per hour, including those delivered under the R-S interval (*i.e.*, following the last response by 20 sec). Generally, the rate of shock increased during conditioning sessions, but only in the tail-shock condition did this overall increase include many more shocks under the S-S interval.

EXPERIMENT II

It was possible that acceleration and suppression in Experiment I were differential non-associative effects of foot shock and tail shock. Rescorla (1967) suggested a random procedure as a control for nonassociative effects in conditioning. The random-control procedure presents the CS and US as frequently as in the conditioning procedure, but these stimuli are presented randomly with respect to one another. In studies that have conducted CS-US pairings separately from avoidance behavior, the random control has been used often (Grossen and Bolles, 1968; Rescorla, 1968; Weisman and Litner, 1969). Use of the random control during ongoing avoidance behavior has been reported for the shuttle response (Scobie, 1972), but not for the wheel-turn response. Experiment II utilized the random-control procedure while rats turned a wheel to avoid foot shock or tail shock.

METHOD

Subjects

Eight rats of the same sex, strain, and age as in Experiment I served. Rats V28 and V29 were discontinued after completing part of the

Fig. 1. Cumulative records of baseline avoidance responding including the last 10 min of avoidance training with foot shock and tail shock for four rats.

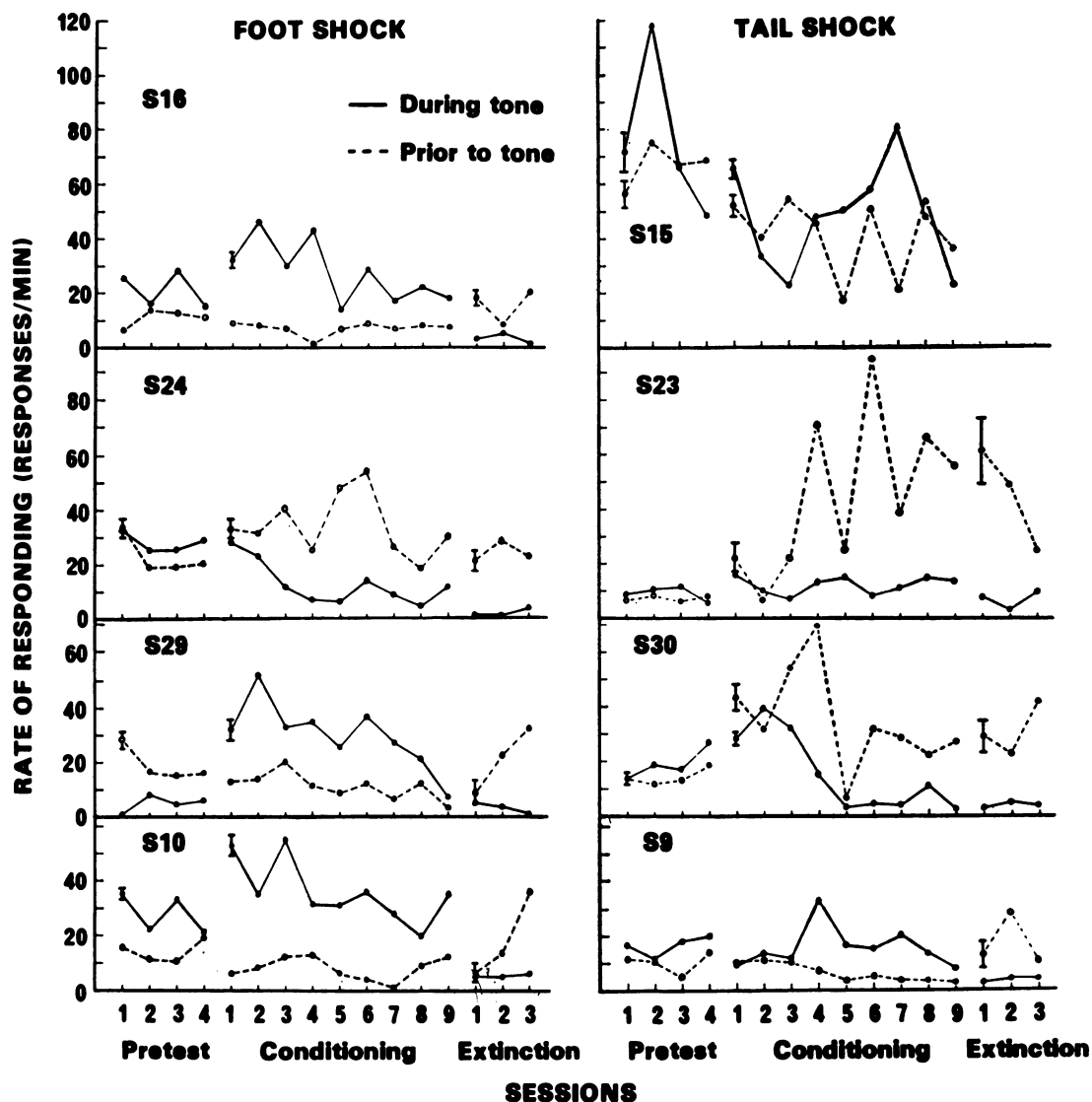


Fig. 2. The rate of responding in the 5 sec just before and during the tone in Experiment I. In Figures 2 and 5, joined brackets shown for the initial session in each phase are the standard errors of the mean within that phase. Brackets did not show effectively and were therefore omitted when a standard error was less than two responses per minute.

procedure in the tail-shock condition because of self-inflicted injuries to the feet and legs.

Procedure

The procedure of Experiment II was the same as in Experiment I, except: free-operant avoidance training was for 24 hr or 26 hr and began with either foot or tail shock followed by the other shock procedure. During the pretest, random control, and extinction phases of Experiment II, four rats (S27, S28, V28, and

V29) had tail shock and four (S17, S18, V27, and V30) had foot shock. Each phase of Experiment II was scheduled over the same number of sessions as the equivalent phase of Experiment I. In fact, only the arrangement of response-independent events in the random-control phase of Experiment II differed from the conditioning phase of Experiment I. In the random-control procedure, 20 response-independent 5-sec tones and 20 response-independent 1-sec shocks were delivered in-

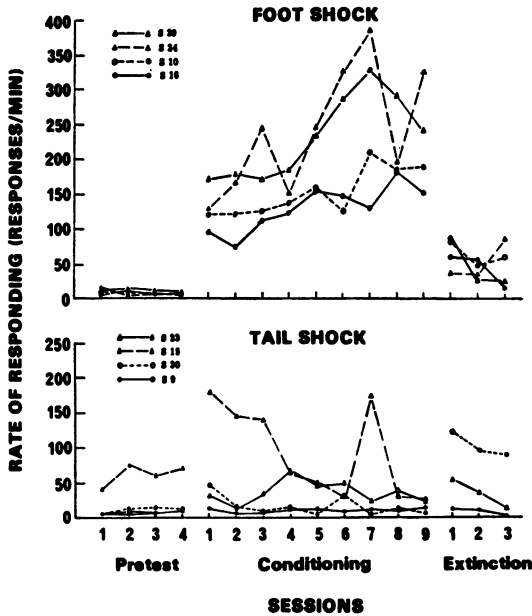


Fig. 3. The rate of responding in the 5 sec immediately after tone offset in Experiment I.

dependently and at random with respect to one another over the final 60 min of 80-min sessions. The delivery of tones and shocks was controlled by independent VT 3-min schedules. The tone schedule had a range of 1 to 5 min and the shock schedule a range of 0.1 to 6.5 min. The range of the shock schedule was greater than the range of the tone schedule because responses were recorded before and after each tone presentation and each tone presentation took 35 sec to complete.

RESULTS

Rates of responding during the 5 sec immediately preceding tone onset and during the 5-sec tone are shown in Figure 5. Tone presentation during pretest increased the rate of responding slightly in some sessions for four of eight rats. During random-control sessions, there were no consistent differences between responding before and during the tone; the tone neither increased nor decreased responding reliably during random-control sessions.

Trials excluded from Figure 5 due to the occurrence of response-dependent foot shock had relative frequencies of 7% in pretest, 20% in random control, and 8% in extinction, while trials excluded due to the occurrence of response-dependent tail shock had relative fre-

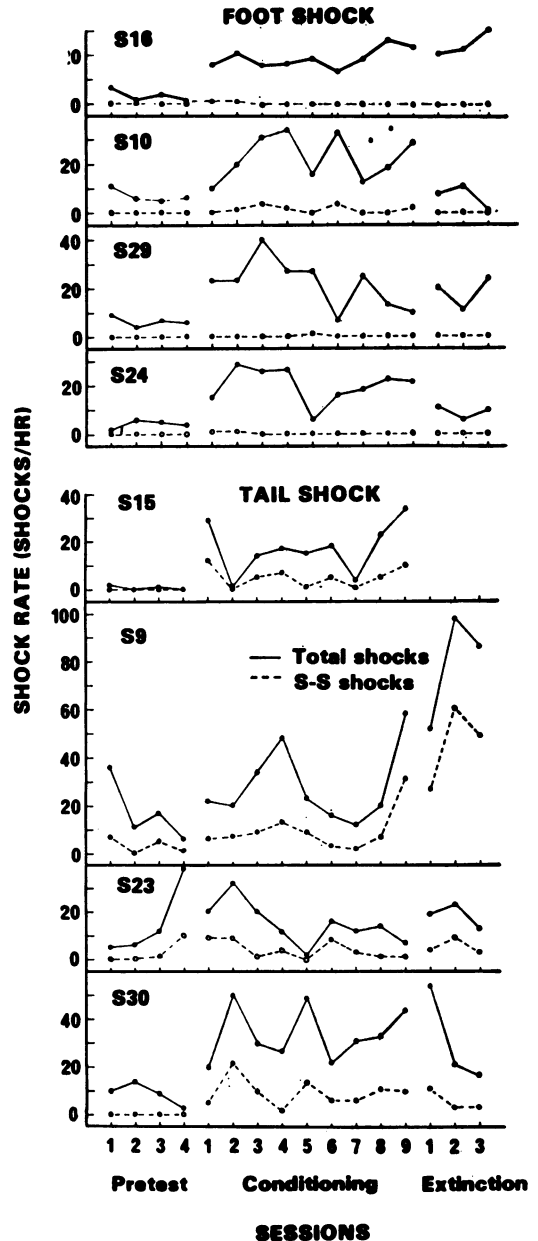


Fig. 4. The rate of response-dependent shock overall and during the shock-shock period in Experiment I.

quencies of 20% in pretest, 20% in random-control sessions, and 2% in extinction.

Figure 6 shows avoidable shocks per hour delivered under the S-S interval and total avoidable shocks. In general, total shock rate increased during random-control sessions; only the S-S shock rates of tail-shock rats increased. Shock rates tended to be lower after response-

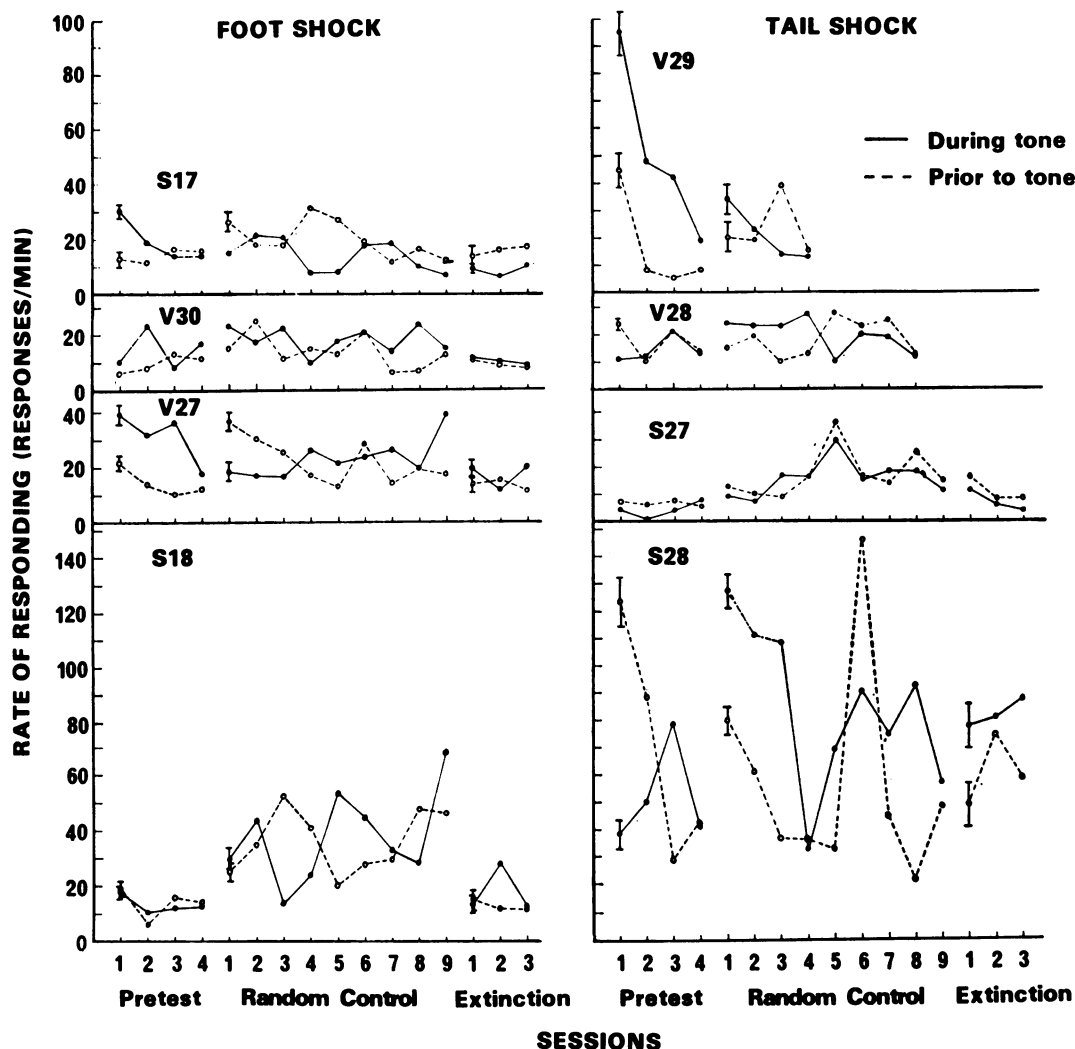


Fig. 5. The rate of responding in the 5 sec just before and during the tone in Experiment II.

independent shocks were eliminated in extinction sessions.

EXPERIMENT III

Two patterns of avoidance responding have been observed during a CS preceding response-independent shock. In the first pattern, responding increased at CS onset, then decreased during the CS (Pomerleau, 1970; Shimoff, 1972). The second pattern was opposite to the first; responding decreased at CS onset then increased during the CS (Rescorla, 1968; Sidman, Herrnstein, and Conrad, 1957; Waller and Waller, 1963). It seemed quite possible

that the variable effects of the CS observed in Experiment I were the result of shifting temporal patterns of responding conditioned to the tone. Experiment III investigated temporal patterns of responding during a CS preceding response-independent shock superimposed on wheel-turn avoidance responding. Comparisons between temporal patterns during the CS were obtained for foot and tail shock US's in the same subjects. Also, Experiment III decreased the rate of CS-US presentation in an attempt to reduce the self-inflicted injury and prevent the increase in response-dependent shock that was observed in Experiments I and II.

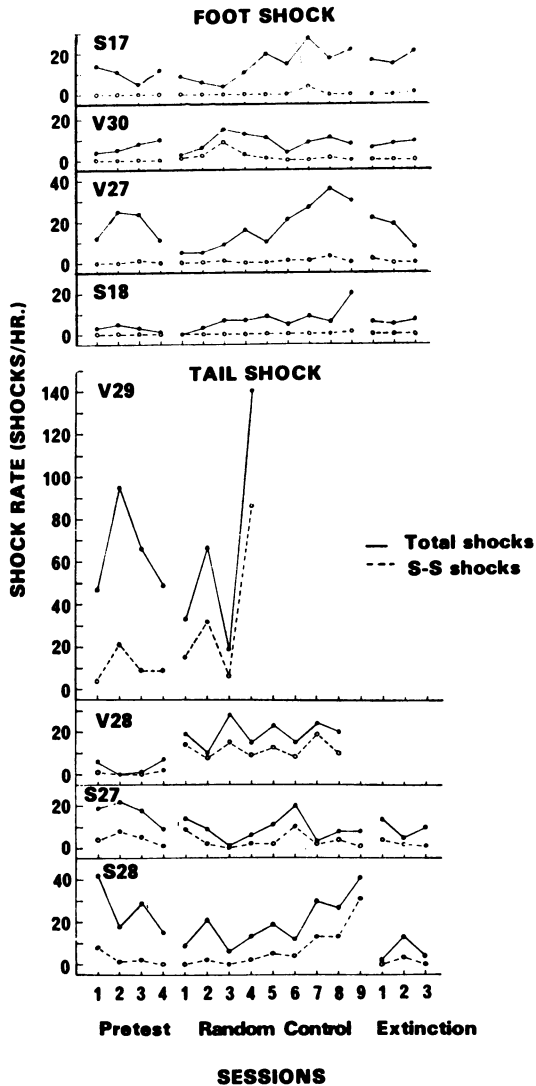


Fig. 6. The rate of response-dependent shock overall and during the shock-shock period in Experiment II.

METHOD

Subjects

Four rats of the same age, sex, and strain as in Experiments I and II served. Rat X17 was discontinued early in tail-shock avoidance retraining. This rat's tail became infected after an experimenter scratched it accidentally with the edge of an electrode.

Procedure

The initial avoidance training phase proceeded as in Experiments I and II, except that the physical locus of shock alternated between the rats' feet and tails from session to session

over six 4-hr and then two 140-min sessions. In the pretest, conditioning, and extinction phases of Experiment III: (a) sessions remained 140 min in duration, (b) 20 tones each 10 sec in duration were presented on a VT 6-min schedule (range 3 to 9 min) during the final 120 min of each session, (c) avoidable shocks scheduled 30 sec before, during, and 30-sec after each tone presentation were omitted. In conditioning phases, 1-sec response-independent shock followed immediately at tone offset. Response-independent shock, but not tone, was omitted from pretest and extinction sessions. Foot shock was scheduled in the initial sequence of pretest, conditioning, and extinction. Then, in subsequent avoidance retraining, pretest, and conditioning phases the rats had tail shock. Finally, the rats were shifted back to conditioning with foot shock. The number of sessions in each phase is shown on the abscissa of Figure 7.

RESULTS

Responding in 2-sec intervals beginning 2 sec before tone onset and ending 10 sec after tone offset are shown in Figures 7 and 8. Pretest, conditioning, and extinction phases with foot shock are shown in Figure 7. Pretest and conditioning phases with tail shock and a final conditioning phase with foot shock are shown in Figure 8. During pretest with foot shock, tone onset reduced responding at least slightly in each rat. During conditioning, the tone controlled a biphasic pattern of responding; an initial decrease in responding by the fourth second after tone onset, followed by an increase in responding generally to a rate higher than before tone onset. After tone offset, response-independent foot shock elicited a short burst of high-rate responding. During extinction, initial suppression of responding continued but increased responding later in the tone was attenuated. High rates of responding following tone offset were also gradually attenuated during extinction.

After the shift to tail shock, the tone had no consistent effect on responding during the pretest, as shown in Figure 8. During conditioning however, response suppression was uniform from 2 sec after tone onset until tone offset. Response-independent tail shock did not elicit an immediate burst of responding. Following the return to foot-shock conditioning, a biphasic pattern of responding was

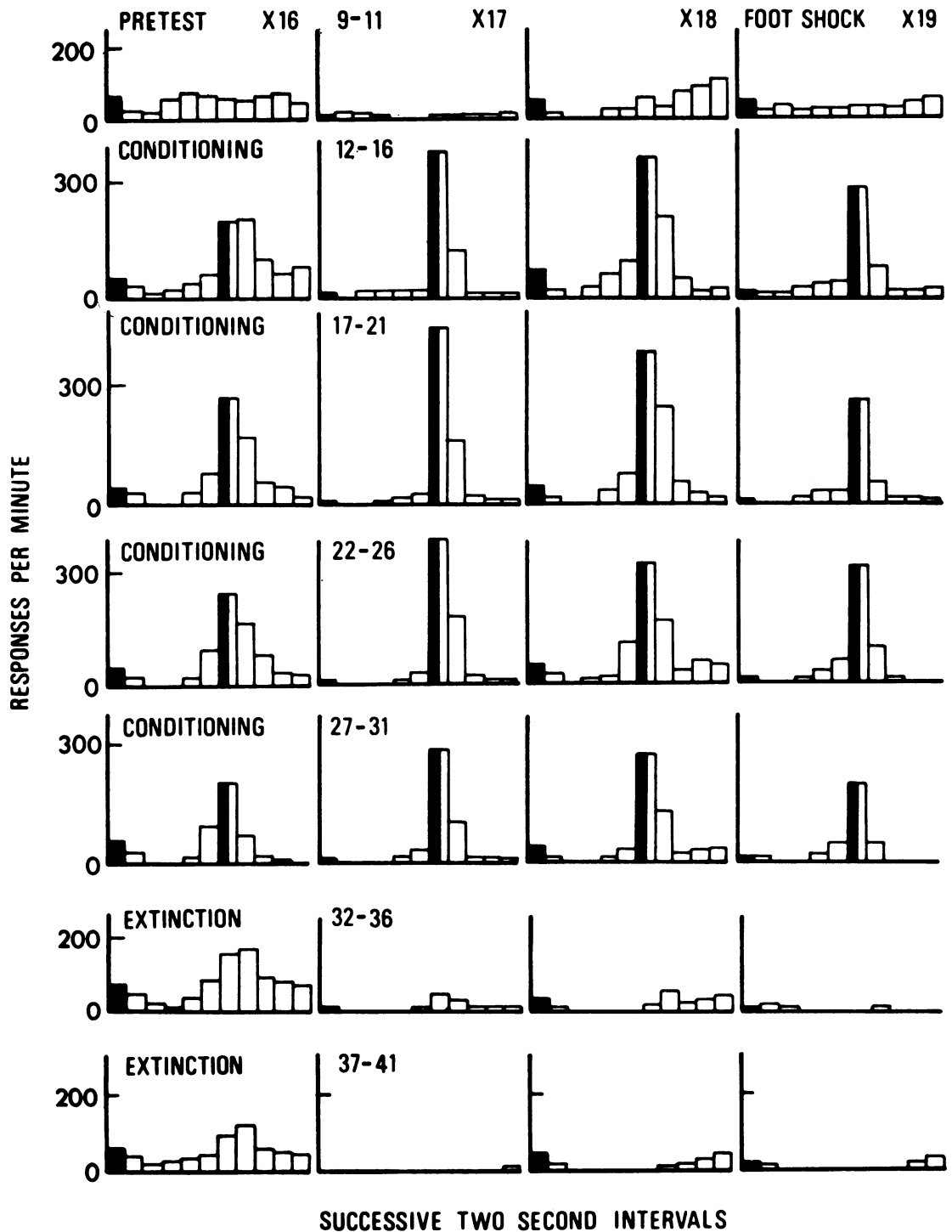


Fig. 7. The rate of responding in 2-sec intervals from 2 sec before tone onset until 10 sec after tone offset during pretest, conditioning, and extinction with foot shock in Experiment III.

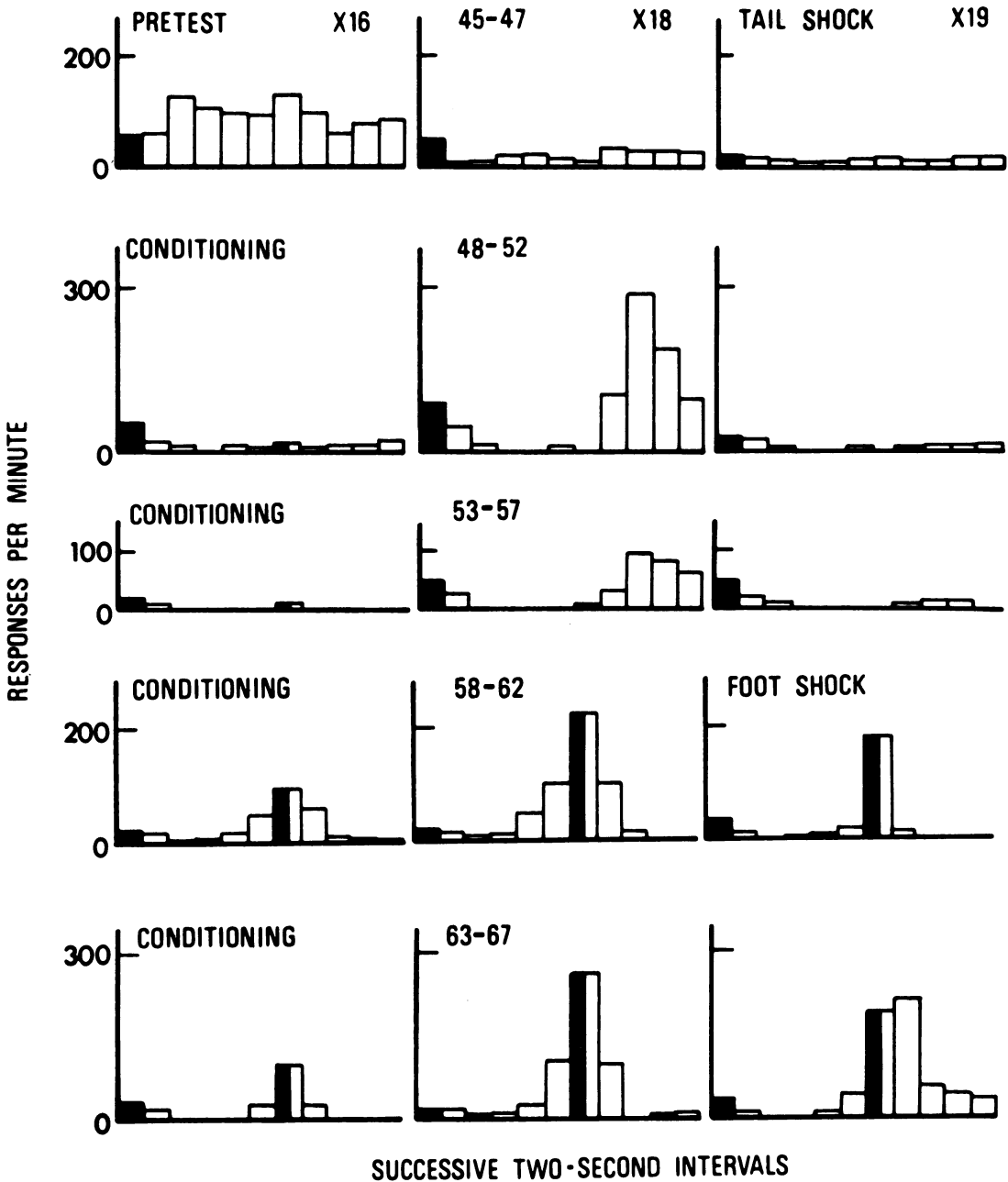


Fig. 8. The rate of responding in 2-sec intervals from 2 sec before tone onset until 10 sec after offset during pretest and conditioning with tail shock and the switch to conditioning with foot shock in Experiment III.

again obtained, but response-independent foot shock elicited somewhat less responding than during earlier foot-shock conditioning.

GENERAL DISCUSSION

The present experiments replicated and extended, in at least a general way, a number of the findings of other investigators. The condi-

tioned stimulus (CS) was not without effects on avoidance responding even before its association with shock. In the present work, a 5-sec tone tended to increase responding, and a 10-sec tone tended to decrease responding. In recent reports, tones have suppressed and white noise has increased shuttle avoidance responding (Scobie, 1972), while flashing lights

have suppressed lever-press avoidance responding (Bryant, 1972). Apparently free-operant avoidance responses are quite sensitive to disruption by novel stimuli.

The random presentation of a CS and shock superimposed on ongoing avoidance responding resulted in no systematic change in the rate of responding during the CS. This finding replicates the results of Scobie (1972), and provides evidence that systematic changes in the rate of avoidance responding elicited by the CS during CS-US pairings are indeed the result of associative conditioning. It has been noted that the rate of response-dependent shock tends to increase during Pavlovian conditioning (Bryant, 1972; Roberts and Hurwitz, 1970; Scobie, 1972). Given that similar increases in shock rate accompanied the random-control procedure in the present work, it seems reasonable to suggest that this increased rate of response-dependent shock is a result of the introduction of 20 or so response-independent shocks per hour during conditioning, and not a result of CS-US pairing *per se*. Foot shock, and in particular response-independent foot shock, often elicited a burst of high-rate responding.

The present experiments also report some interesting new findings. In extinction, following conditioning with either tail or foot shock as the US, response rates during the CS were suppressed whether they had been increased or suppressed during the CS in conditioning. Also, responding at CS offset, the temporal locus of the US during conditioning, continued at a diminished rate during extinction. Overall measures of Pavlovian conditioning, obtained by comparing responding during the CS to responding before the CS may generate highly variable results because of temporal patterns of responding occurring within the CS. In Experiment III, a distinctive temporal pattern of responding was observed during the CS preceding foot shock; low response rates early in the CS were followed by increased responding to CS offset. This biphasic pattern is reminiscent of results reported by Kelleher, Riddle, and Cook (1963), Rescorla (1968), Roberts and Hurwitz (1970). Temporal patterns of avoidance responding are not always seen during the CS preceding shock. Some procedures (e.g., Scobie, 1972) generate response rates far too low for patterned responding to be discerned. However, wheel-turn avoidance re-

sponding usually occurred at rates in excess of 10 responses per minute, and often at rates of over 20 responses per minute. These rates were sufficient for observation of biphasic patterns. However, under similar conditions, the CS preceding tail shock generated only monophasic suppression of responding. Moreover, the pattern shifted rapidly with the change from tail to foot shock in the final phases of Experiment III.

There seem to be two possible accounts of the differential effects of the physical locus of the shock US. One account is based on the differences in the potential modifiability of foot shock and tail shock. This account is strengthened by evidence that weaker shock generates increased responding, while stronger shock generates suppression to the CS (Scobie, 1972). Modification of foot shock may decrease its strength relative to tail shock and produce the findings reported here. The second account is based on the differences in the behaviors elicited by the two US's. This account is strengthened by evidence from the present work that foot and tail shock do elicit topographically distinct behaviors. Foot shock elicited jumping from the grid floor and a burst of wheel turning. In response to tail shock, rats turned from the wheel toward the source of shock and vigorously gnawed the grid floor of the stall and occasionally their back paws. These shock-elicited behaviors usually persisted for several seconds after shock offset. The fact that behaviors elicited by tail shock were incompatible with wheel turning may account for the high proportion of S-S shock received by the tail-shock rats. Similarly, the physical locus of the US may determine the topography of the conditioned defense reaction, just as it determined the topography of the unconditioned response (Bolles, 1970). Perhaps compatibility between foot-shock elicited behaviors and wheel turning may account for increased responding to the CS; incompatibility between tail-shock elicited reactions and wheel turning may account for decreased conditioned responding to the CS. Both accounts of differences in the effects of US's at different physical loci are plausible, but the evidence for or against either is not yet convincing.

REFERENCES

- Barabee, H. E. and Weisman, R. G. On the failure of transfer of control from separately conducted

- Pavlovian conditioning to free-operant avoidance conditioning in rats. *Learning and Motivation*, 1975, **6**, 498-511.
- Bolles, R. C. Species-specific defense reactions and avoidance learning. *Psychological Review*, 1970, **77**, 32-48.
- Bryant, R. C. Conditioned suppression of free-operant avoidance. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 257-260.
- Davis, H. and Hubbard, J. Conditioned vocalization in rats. *Journal of Comparative and Physiological Psychology*, 1973, **82**, 152-158.
- Grossen, N. E. and Bolles, R. C. Effects of classical conditioned 'fear signal' and 'safety signal' on non-discriminated avoidance behavior. *Psychonomic Science*, 1968, **11**, 321-322.
- Hurwitz, H. M. B. and Roberts, A. E. Conditioned suppression of an avoidance response. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 275-281.
- Kelleher, R. T., Riddle, W. C., and Cook, L. Persistent behavior maintained by unavoidable shocks. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 507-517.
- Pomerleau, O. F. The effects of stimuli followed by response-independent shock on shock-avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1970, **14**, 11-21.
- Rescorla, R. A. Pavlovian conditioning and its proper control procedures. *Psychological Review*, 1967, **74**, 71-80.
- Rescorla, R. A. Pavlovian conditioned fear in Sidman avoidance learning. *Journal of Comparative and Physiological Psychology*, 1968, **65**, 55-60.
- Reynierse, J. H., Scavio, M. J., and Ulness, J. D. An ethological analysis of classically conditioned fear. In J. H. Reynierse (Ed), *Current issues in animal learning: A colloquium*. Lincoln: University of Nebraska Press, 1970. Pp. 33-54.
- Roberts, A. E. and Hurwitz, H. M. B. The effect of a pre-shock signal on a free-operant avoidance response. *Journal of the Experimental Analysis of Behavior*, 1970, **14**, 331-340.
- Scobie, S. R. Interaction of an aversive Pavlovian conditional stimulus with aversively and appetitively motivated operants in rats. *Journal of Comparative and Physiological Psychology*, 1972, **79**, 171-188.
- Shimoff, E. Avoidance responding as a function of stimulus duration and relation to free shock. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 451-461.
- Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 1953, **118**, 157-158.
- Sidman, M., Herrnstein, R. J., and Conrad, D. G. Maintenance of avoidance behavior by unavoidable shocks. *Journal of Comparative and Physiological Psychology*, 1957, **50**, 553-557.
- Teyler, T. J. Effects of restraint on heart-rate conditioning in rats as a function of US location. *Journal of Comparative and Physiological Psychology*, 1971, **77**, 31-37.
- Waller, M. B. and Waller, P. F. The effects of unavoidable shocks on a multiple schedule having an avoidance component. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 29-37.
- Weisman, R. G. and Litner, J. S. Positive conditioned reinforcement of Sidman avoidance behavior in rats. *Journal of Comparative and Physiological Psychology*, 1969, **68**, 597-603.

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